STRUCTURAL HEALTH MONITORING FOR HETEROGENEOUS SYSTEMS

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Abstract

A structural health monitoring (SHM) framework is being developed for characterization, detection, quantification and classification of damage in heterogeneous systems. At present, the important elements of this piezoelectric sensor integrated SHM system are: (i) high fidelity analysis capable of accounting for complex structural deformation/stress fields due to anisotropy and two-way electro-mechanical coupling due to distributed self-sensing sensors, (ii) wave propagation in heterogeneous media and characterization of material attenuation, (iii) strain based and local energy based damage indicators for damage detection, (iv) optimal sensor placement techniques, (v) methodology for localized analysis of waveforms obtained from damaged structures and time-frequency representations (TFRs), with a broader view of damage quantification, (iv) signal processing technique based on the matching pursuit decomposition (MPD) and (v) Artificial Neural Networks (ANN) based techniques for detecting damage (both existing and progressive).

The analysis techniques developed are based on higher order and layerwise displacement field formulations, which allows formulation of through-thickness transverse shear effects and accurate descriptions of ply level stresses. The fully coupled electro-mechanical constitutive relations allows for complete energy transfer between the piezoelectric and the mechanical fields due to distributed transducers. A fundamental investigation into fiber/matrix wave propagation and scattering has been conducted to understand the phenomenon of multiple scattering of waves in heterogeneous media. An analytical model has been developed showing the effects on wave scattering and attenuation due to anisotropy and sensor observation angle. A local energy based inspection method and an optimal sensor placement technique has been developed in the presence of noise through characterization of sensor/host structure coupling, sensing capability and sensor sensitivity. An MPD algorithm has been developed for detection and localization of seeded delamination in composite structures. Characterization of sensor signals is conducted to interpret the influence of delamination in composite plates using the MPD technique. This has been accomplished by decomposing the signal in terms of wave-based dictionary elements (Figure1) and finally utilizing the time-of-flight information of these individual components to determine the location and size of the delamination. This model has been further extended to extract some of those feature components based on the characteristics of "multiple-harmonic" vibrations. A technique has also been developed to investigate the possibility of using agents composed almost exclusively of ANNs for detecting damage based on the distribution of a modal strain based damage indicator. The developed methodology consists of three key elements (a) a numerical model that is used to compute the damage index distribution of a given damage pattern, (2) an ANN trained to encapsulate the numerical model, and (3) a Genetic Algorithm, which working in conjunction with the ANN model locates and describes the damage (Figure 2) accurately.

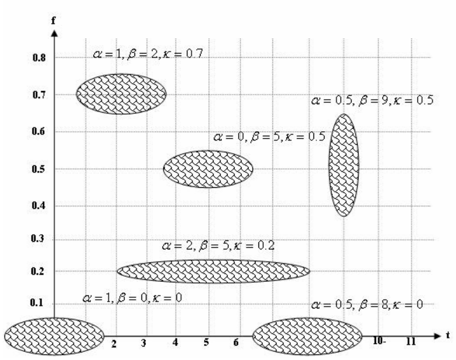

Figure 1: Time-frequency atoms with varying scaling factors

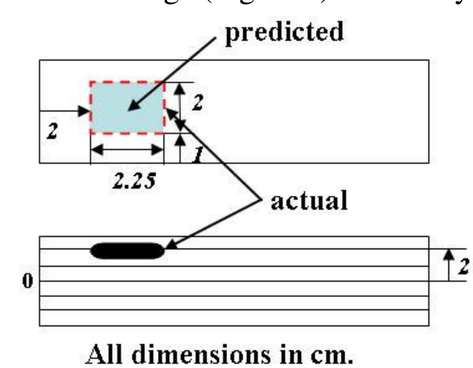

Figure 2: Prediction of single seeded delamination